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GARFIELD ABBREVIATED CLASS II INSPECTION AND SILVER CREEK RECEIVING WATER STUDY

by

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ABSTRACT

Garfield WTP did not comply with its NPDES permit during a survey in October 1986. The plant exceeded the numerical limit and pollutant removal requirement for BOD. TSS was within its numerical limit, but did not meet the removal requirement. WTP effluent accounted for 70 percent of the flow in the upper reaches of Silver Creek and 20 percent at the creek mouth. Water quality violations in Silver Creek included depressed oxygen, excessive TSS, and toxic levels of un-ionized ammonia and total residual chlorine. Other stream sources include unknown sources above the discharge point and livestock wastes. Water quality in Silver Creek can be improved by eliminating direct discharge of the WTP to the creek, preventing livestock access, and eliminating the unknown upstream source.

INTRODUCTION

The town of Garfield is located about 16 miles north of Pullman, Washington. The Garfield Wastewater Treatment Plant (WTP) provides secondary treatment for a community of 600 people. The WTP consists of a clarifier, biofilter, anaerobic digester, and sludge drying beds. Treated effluent is chlorinated and flows about 1400 feet to Silver Creek (Figure 1).

Silver Creek passes two agricultural chemical suppliers (Palouse Producers, Inc. and McGregor Co.) located in town. The WTP effluent enters Silver Creek downstream of the town. From there the creek flows westward 4.5 miles until it joins the Palouse River at Elberton.

Garfield WTP was built about 1951. An efficiency study of the plant was done in 1974, but the impact of the effluent on Silver Creek has never been measured. The Eastern Regional Office (ERO) of the Department of Ecology requested Ecology's Water Quality Investigations Section (WQIS) to evaluate the performance of the WTP and to measure the effect of the discharge on Silver Creek. The field survey was carried out on October 7 and 8, 1986. The study was performed by the author and Lynn Singleton with the assistance of Carl Nuechterlein and Lawrence Peterson of Ecology's ERO. Jim Bolyard, the WTP operator, was on hand during the work.

The survey objectives were as follows:

1. Assess the treatment efficiency of Garfield WTP and compliance with their NPDES (National Pollutant Discharge Elimination System) permit.

2. Conduct an analysis of loading from the plant during seasonal low flow and determine any receiving water impacts.

The data will establish a water quality baseline. ERO will use the results to determine what, if any, treatment upgrade may be necessary.

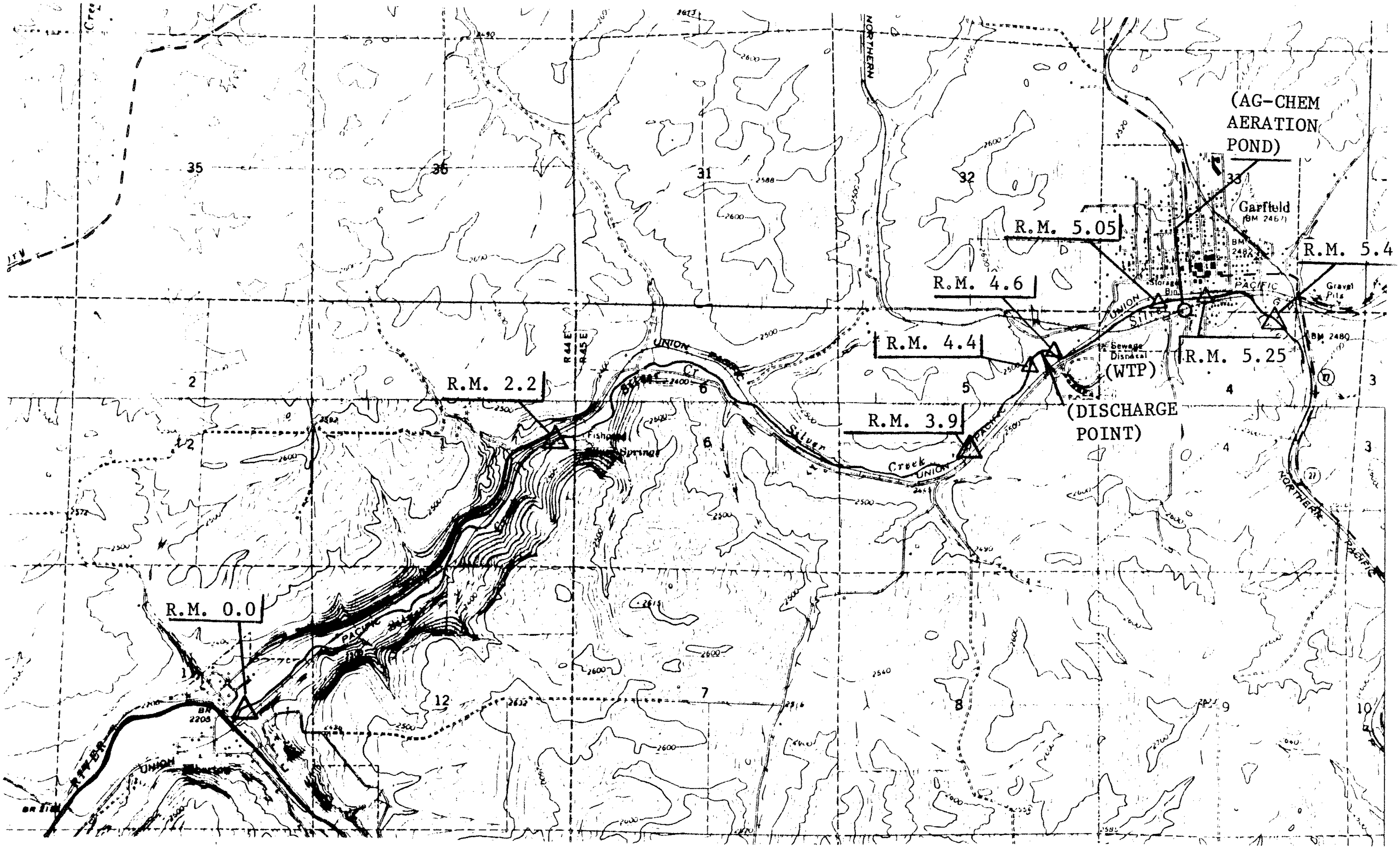


Figure 1. Garfield WTP discharge point and sampling sites on Silver Creek during an abbreviated Class II inspection/receiving water study in October, 1986.

METHODS

Ecology's ISCO composite samplers collected 200 mL samples every 30 minutes for 24 hours from the WTP influent and effluent. Garfield's Jim Bolyard manually composited two grabs (his normal practice) taken at 1700 hours on October 6 and 0800 hours on October 7.

Ecology and Garfield composite samples were well mixed and subsamples taken for analysis of turbidity, conductivity, chloride, COD (chemical oxygen demand), BOD (biochemical oxygen demand), and TSS (total suspended solids). In addition, the Ecology compositor subsamples were analyzed for nitrate+nitrite and ammonia, total phosphorus, and total alkalinity (as $CaCO_3$). Subsamples from the Ecology composite sampler were sent to the Colfax WTP laboratory (the contract laboratory for Garfield WTP). The subsamples were analyzed for BOD and TSS as a laboratory quality-assurance check.

Three sets of grab samples were taken from the influent and effluent during the course of the WTP inspection. Laboratory analyses were performed for turbidity, conductivity, chloride, COD, fecal coliform, nitrate+nitrite and ammonia, total phosphorus, TSS, and total hardness (as $CaCO_3$). Also, total- and free-chlorine residuals were measured in the effluent with a LaMotte chlorine comparator. Effluent samples for fecal coliform analysis were placed in bottles treated with sodium thiosulfate to arrest disinfection by the chlorine.

A brief study was conducted to estimate the die-off of FC due to chlorine contact in the discharge line. Five mL of Rhodamine wt dye were dropped into the discharge line at its head. It emerged in Silver Creek about 30 minutes later. A large sample of effluent was taken at the WTP and well mixed. Two subsamples were poured into two FC sample bottles. The first ("initial") contained thiosulfate to stop chlorine action to indicate FC levels at that point. The other bottle (containing no thiosulfate) was placed in the dark at ambient temperature (with the first) to partially simulate travel time in the discharge line. (Full simulation was not possible because the bottle lacked agitation while in dark storage.) Chlorine action in this bottle was stopped after 30 minutes when the contents were dumped into a thiosulfate-treated bottle. The rate of die-off was determined as follows:

$$\text{Percent reduction FC} = \{\text{Final [FC]} / \text{Initial [FC]}\} * 100 \qquad (1)$$

Samples and instrument readings were taken at nine places along Silver Creek above and below the WTP discharge point (Figure 1). These were analyzed for turbidity, chloride, COD, fecal coliform, nitrate+nitrite and ammonia (as nitrogen), total phosphorus, and TSS. Instrument readings included pH, conductivity, and dissolved oxygen (D.O.). Both the Orion pH meter and the YSI D.O. meter were calibrated at the beginning of each day. Calibration was rechecked at the end of each day's work. On several occasions, it was necessary to collect Winkler D.O. samples when the instrument was not available. These samples were preserved by adding $MnSO_4$ and AIA reagents and storing in the dark until acidification and titration later.

Samples for laboratory analysis were stored in ice chests and sent to the Manchester Environmental Laboratory so that bacteriological analysis could begin within 30 hours of sampling. Analyses were performed according to procedures in APHA (1985) and EPA (1979).

Un-ionized ammonia levels were calculated from temperature and pH by computer with a program developed by Yake and James (1983).

Stream flows were measured at sample sites below the WTP with a Marsh-McBirney flow meter and a top-setting rod. Flow sites above the WTP discharge had too low flow for stream flow measurement. WTP flow was determined by placing a Manning Dipper portable flowmeter at a Parshall flume built into the effluent channel of the WTP. Loads at the WTP and stream sites were calculated for several pollutants by using IHD-WHO (1978):

$$L = f\ c\ d \qquad (2)$$

where L = load (lb/day)
c = concentration of material (mg/L)
d = stream or WTP flow (cfs)
and f = 5.3936 (conversion factor)

Loads of fecal coliform were calculated from the above equation as adapted from Kittrell (1969):

L = fecal coliform load (no./day)
c = concentration of FC (no./100mL)
d = stream or WTP flow (cfs)
and f = 24,600,000 (conversion factor)

RESULTS AND DISCUSSION

Garfield WTP Abbreviated Class II Inspection

Figure 2 shows the physical structure and flow pathways within Garfield WTP. It appears that the clarifier receives comminuted raw influent and flow from the biofilter. Thus the clarifier serves as both a primary and secondary clarifier (Reif, personal communication). The mixing of biofilter effluent with untreated influent reduces treatment efficiency. Upgrade of the plant should include an additional clarifier.

Table 1 summarizes water quality data gathered from the WTP influent and effluent with limits from the NPDES permit. Temperature, pH, and conductivity showed little change as a result of treatment, and pH was within permit limits. Treatment resulted in substantial increases in dissolved oxygen and chlorides. The increase in chlorides is consistent in all grabs and the composite samples. The cause may be leaching of chlorine from the rock in the trickling filter, or evaporation. An unknown cleaning or grit removal agent may also be the cause, and the operator should be consulted.

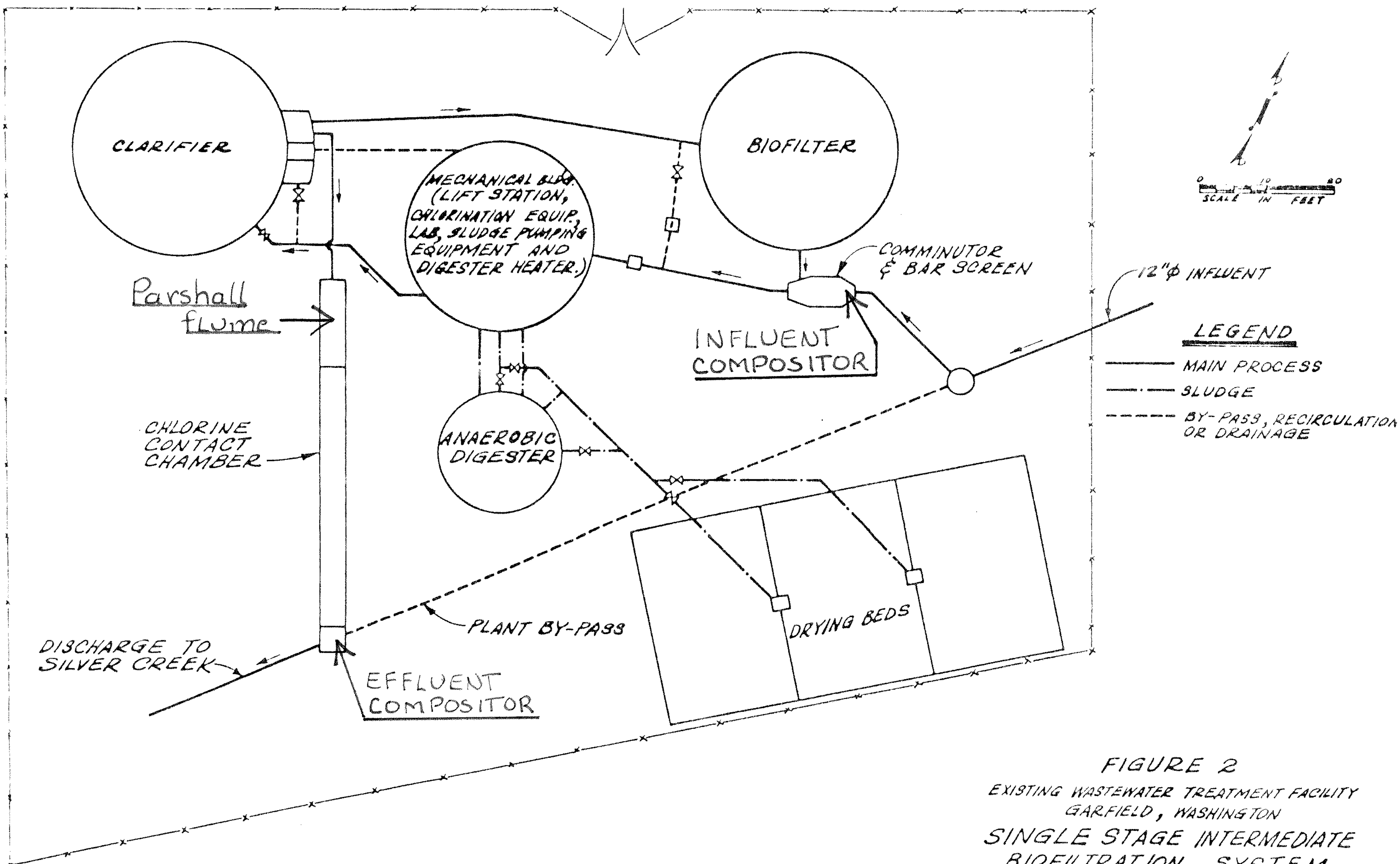


FIGURE 2
EXISTING WASTEWATER TREATMENT FACILITY
GARFIELD, WASHINGTON
SINGLE STAGE INTERMEDIATE
BIOFILTRATION SYSTEM

Table 1. Water quality data gathered from the influent and effluent of Garfield WTP during a Class II inspection of the facility in October 1986. The results include a comparison with NPDES permit requirements.

	Date	Time	Temperature (^oC)	Diss. Oxygen (mg/L)	pH (S.U.)	Spec. Cond. (umhos/cm) Field	Spec. Cond. (umhos/cm) Lab	Cl. (mg/L)	COD (mg/L)	BOD (mg/L)	Fecal Coliform (#/100 mL)	$NO_3 + NO_2$ (mg/L)	Ammonia (mg/L) Total	Ammonia (mg/L) Un-ion.	T. Phos. (mg/L)	TSS (mg/L)	Turbidity (NTU)	T. Hardness (mg/L)	Alk. (mg/L as $CaCO_3$)	T. Chlor. (mg/L)
Grab Samples																				
Influent	10/7/86	1100	18.6	2.5	7.3	500	*	24	360	*	1,600,000	0.48	9.7	*	11	63	24	140	*	*
		1530	17.3	*	7.2	483	*	26	220	*	1,400,000	0.42	9.4	*	9.7	62	17	140	*	*
	10/8/86	1150	17.0	6.5	7.4	500	*	30	230	*	*	0.40	12	*	7.6	120	22	*	*	*
	Average		17.6	4.5	7.3	494	*	27	270	*	1,500,000	0.43	10.4	*	9.4	82	21	140	*	*
Effluent	10/7/86	1115	15.9	6.2	7.6	460	*	46	120	*	170	1.8	12	0.138	6.4	27	14	140	*	2.5
		1530	16.2	6.8	7.5	493	*	42	110	*	20	2.1	10	0.094	6.6	15	13	140	*	2.5
	10/8/86	1145	15.9	6.1	7.6	460	*	32	110	*	17	1.5	12	0.138	6.4	24	13	*	*	2.5
	Average		16.0	6.4	7.5	471	*	40	113	*	39	1.8	11	0.123	6.5	22	13	140	*	2.5
Composite Samples (analyzed by Ecology laboratory)																				
Influent	Ecology		*	*	*	*	577	27	230	110	*	0.42	12	*	6.7	110	20	*	230	*
	Garfield		*	*	*	*	619	30	360	96	*	*	*	*	*	210	32	*	*	*
Effluent	Ecology		*	*	*	*	595	38	140	48	*	1.1	11	*	6.6	24	12	*	210	*
	Garfield		*	*	*	*	587	36	120	42	*	*	*	*	*	19	12	*	*	*
[effluent]/[influent][A]			*	*	*	*	1.0	1.4	0.6	0.4	*	2.6	0.8	*	1.0	0.22	0.6	*	0.9	*
NPDES Permit	Monthly Ave.		*	*	6.5-8.5	*	*	*	*	30	200	*	*	*	*	30	*	*	*	*
Require-ments	Weekly Ave.		*	*	6.5-8.5	*	*	*	*	45	400	*	*	*	*	45	*	*	*	*
[effluent]/[influent]			*	*	*	*	*	*	*	0.15B	*	*	*	*	*	0.15B	*	*	*	*

* = Not applicable or no data.
A = Calculation based on Ecology composite sample only.
B = If influent BOD or suspended solids concentration is less than 200 mg/L, the monthly average effluent limits shall be 15 percent of such influent concentrations.

The strength of Garfield's influent appeared to be near the lower end of the typical range (Metcalf and Eddy, 1972). Estimated flows (0.076 MGD) were about as expected based on a 100 gpd per capita input.

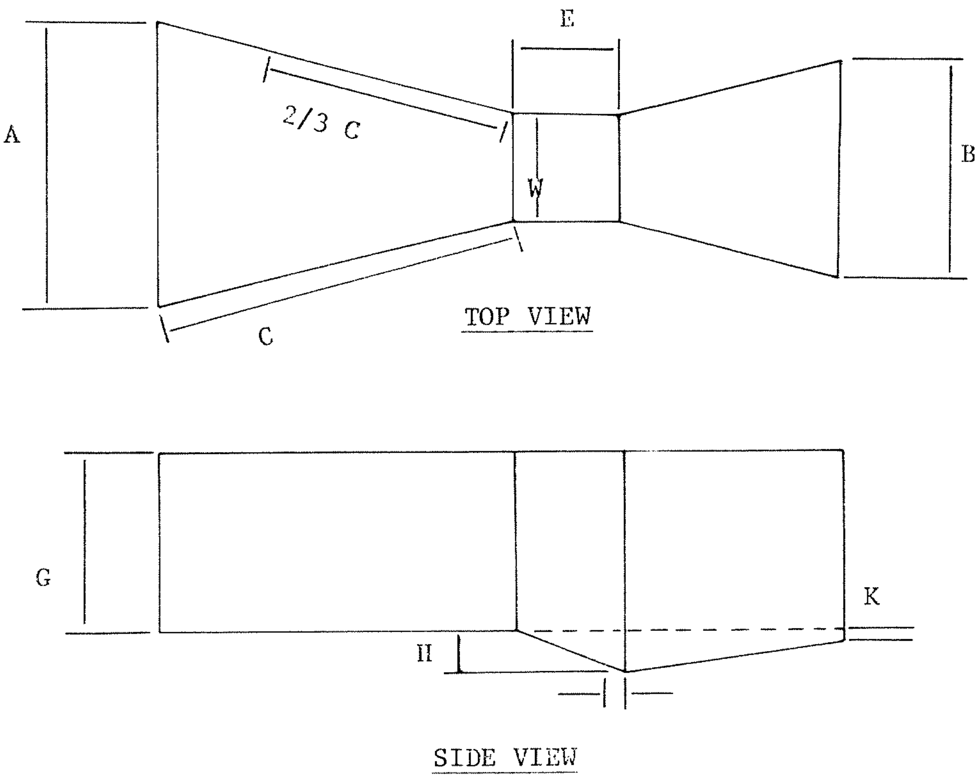
After treatment, total phosphorus levels were reduced slightly. Nitrate+nitrite increased. Ammonia levels were relatively unchanged by treatment. The proportions of nitrate+nitrite to ammonia suggest that little nitrification was occurring (W. Yake, 1987, personal communication).

Turbidity, total suspended solids, BOD, and COD levels were reduced by the treatment. Compositor results suggest that BOD exceeded the monthly average permit limit and was slightly above the weekly limit as well. When influent BOD is less than 200 mg/L, the permit specifies an effluent limit of 15 percent of influent levels. Compositor results suggest that the treatment process did not achieve this level of removal. TSS results seemed to comply with the numerical limits of the permit. However, like BOD, influent TSS was less than 200 mg/L and the percent-of-influent limit was applicable. Effluent TSS (22 percent of influent) exceeded the limit slightly.

Fecal coliform levels were well within permitted limits. The effluent values shown in Table 1 were from samples taken downstream of the chlorine contact chamber (Figure 2). Use of dye indicated a detention time of 15 minutes within the chlorine contact chamber. The chlorine level after passing through the chamber was 2.5 mg/L, and FC was 69/100 mL. Further die-off occurred in the discharge line. Results of the die-off study showed a reduction of 96 percent (from 69 FC/100 mL to 3 FC/100 mL) during a 30-minute travel time within the discharge line. Ecology (1985) recommends a detention time of one hour under average conditions and 20 minutes under maximum flow. The combined detention time (contact chamber plus discharge line) of 45 minutes is close to the recommended time.

The high chlorine residual at the plant and the large FC reduction in the discharge line suggest that the level of chlorine residual injected into the discharge (2.5 mg/L) is unnecessarily high. There is no numerical limit for chlorine residual in the current NPDES permit. The chlorine level at the WTP was five times higher than the usual limit (0.5 mg/L). The chlorine injection resulted in significant levels of chlorine detected in the receiving waters. This will be discussed later.

As a routine procedure, WTP flow is estimated daily by the plant operator. The exact method is unknown at present (C. Nuechterlein, 1987, personal communication). The waste stream passes through a Parshall flume before reaching the outfall line (Figure 2). The dimensions of the flume were measured and compared with standard dimensions found in Stevens (1978). The findings indicate that the flume was not constructed accurately (Figure 3). In addition, the throat appears to have been prefabricated out of steel plate. The bottom plate is missing and the underlying concrete surface is rough. The sides are badly rusted.



DIMENSION CODE	STANDARD DIMENSION DIMENSION * (inches)	MEASURED DIMENSIONS (inches)
A	10 3/16	10
B	7	6 3/4
C	18 3/8	18
E	6	6
G	15	13 1/2
H	2 1/4	1/2
K	1	**
W	3	2 7/8

* From Stevens (1978).

** In a standard Parshall flume, Y = G + K. But at Garfield WTP, G = 13 1/2 inches and Y = 13 inches.

Figure 3. A comparison of standard dimensions for Parshall flumes with measurements taken at Garfield WTP.

There are several other problems that need attention. The ladder for the biofilter (Figure 2) is rusted through and needs replacement. The Dorco distribution arm is powered by water pressure generated by plant flow. When WTP flow is low, the arm stops and wastewater becomes concentrated at one place. If the stoppage is extended, microbial growth elsewhere would become stressed or die from desiccation. Operational or equipment changes should be made to allow rotation at all times. A possible solution is the placement of a recirculation pump in a sump that would provide a constant flow of clarifier water to the biofilter regardless of the influent flow (Reif, personal communication). The distribution arm could be hydraulically driven with that flow.

Figure 4 is the record of the portable flowmeter. The flow calculated from this record was 0.076 MGD. Wastewater tended to move in slugs, and the flume was essentially dry between pump cycles. During the same day, the flow estimated by the plant operator (DMR report submitted a month after the survey) was 0.094 MGD. Since the method used to measure flow is not known (and therefore its accuracy cannot be determined), the flowmeter value was used to calculate plant loads.

The intermittent nature of the discharge may be related to the high levels of chlorine residual discussed earlier. It is possible that the varying plant flow causes uneven chlorination of the effluent. This issue should be explored and a correction (if necessary) included in upgrade planning.

The average un-ionized ammonia in three grabs of effluent was 0.123 mg/L, over six times higher than the four-day chronic criterion (0.021 mg/L) established in EPA (1986). Un-ionized ammonia levels in individual effluent grabs was at or near the one-hour acute criterion (0.11 to 0.13 mg/L).

Loads of several parameters are summarized in Table 2. The results (based on data in Table 1) indicate that the Garfield WTP was well within the limits for total poundage of BOD and TSS imposed by the NPDES permit. This would have also been true if the greater flow determined by the routine WTP procedure had been used.

Table 3 compares the results of split composite samples for BOD and TSS analyzed by Ecology's Manchester laboratory and the Colfax WTP laboratory. The data suggest a lack of comparability. While the results from the split samples from the Ecology influent composite are nearly equal (110 vs. 114 mg/L), the result from the Garfield composite analyzed by the Colfax lab seemed excessively high (96 vs. 159 mg/L). TSS results from the Colfax lab from both influent composites were significantly lower than the results from Manchester (110 vs. 84 mg/L or 24 percent lower; 210 vs. 134 mg/L or 36 percent lower).

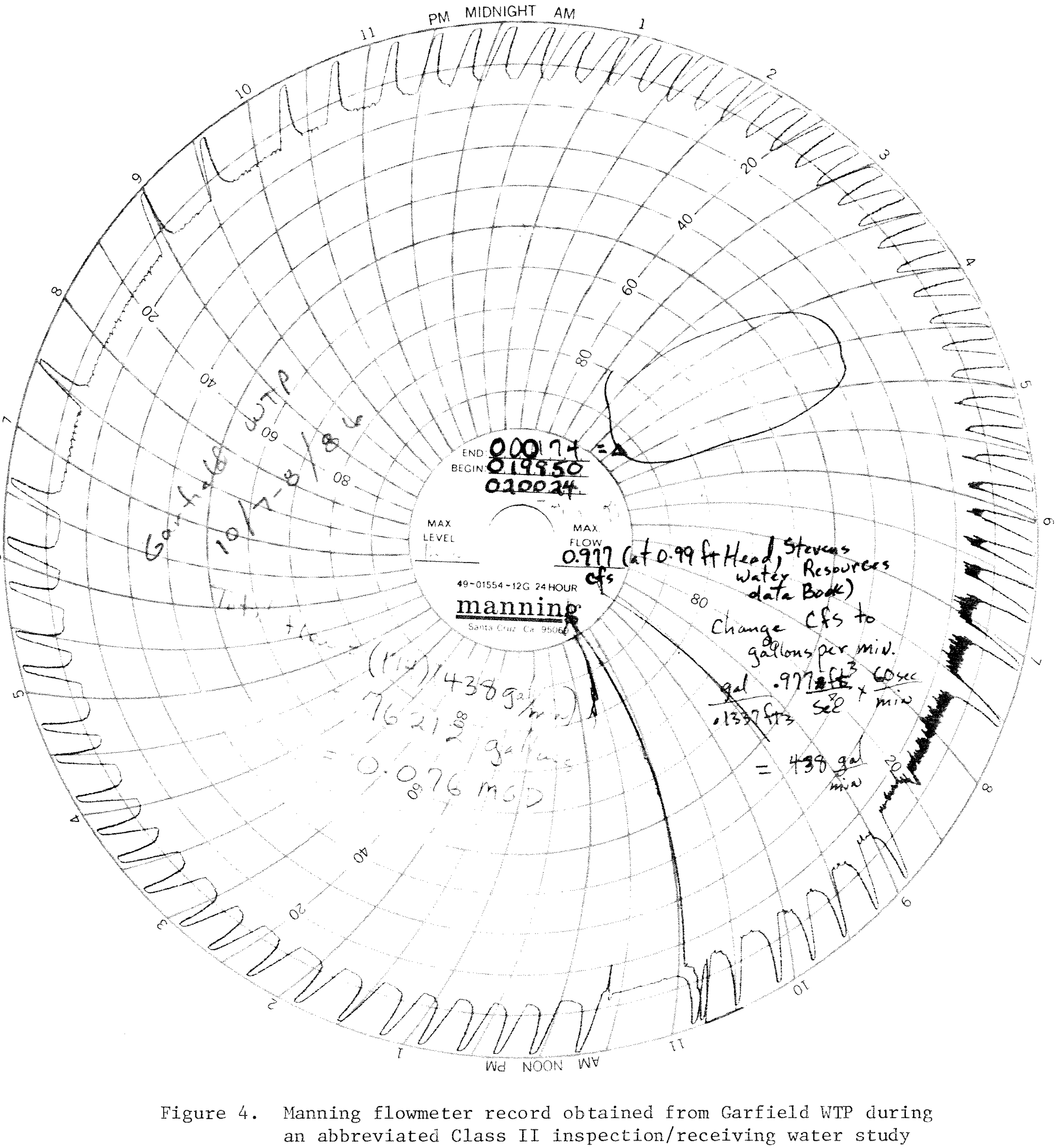


Figure 4. Manning flowmeter record obtained from Garfield WTP during an abbreviated Class II inspection/receiving water study conducted during October, 1986.

Table 2. Loads calculated for the influent and effluent of the Garfield WTP for several water quality parameters. The results include a comparison with NPDES requirements.

	Date	Time	Flow (MGD)	Chlorine (lbs/day)	Chemical Oxygen Demand (lbs/day)	Biochem. Oxygen Demand (lbs/day)	Fecal Coliform No./day (E+07)	Nitrate + Nitrite (lbs/day)	Ammonia (lbs/day)	Total Phosphorus (lbs/day)	Total Suspended Solids (lbs/day)
Grab Samples											
Influent	10/7/86	1100	0.07	14	214	*	4.3E+05	0.3	5.8	6.5	37
		1530	0.07	15	131	*	3.8E+05	0.2	5.6	5.8	37
	10/8/86	1150	0.07	18	136	*	*	0.2	7.1	4.5	71
Effluent	10/7/86	1115	0.07	27	71	*	4.6E+01	1.1	7.1	3.8	16
		1530	0.07	25	65	*	5.4E+00	1.2	5.9	3.9	9
	10/8/86	1145	0.07	19	65	*	4.6E+00	0.9	7.1	3.8	14
Average Effluent			*	24	67	*	1.0E+08[1]	1.1	6.7	3.8	13
Composite Samples (analyzed by Ecology laboratory)											
Influent	Ecology		0.07	16	136	65	*	0.2	7.7	4.0	65
	Garfield		0.07	18	214	57	*	*	*	*	125
Effluent	Ecology		0.07	23	83	28	*	0.7	6.5	3.9	14
	Garfield		0.07	21	71	25	*	*	*	*	11
Permit											
NPDES Permit Require-ments	Monthly Average		0.20	*	*	100	*	*	*	*	100
	Weekly Average		0.20	*	*	125	*	*	*	*	125

* = Not applicable or no data.

[1]Geometric mean.

Table 3. Comparison of split-sample results from composite samples collected during a Class II inspection of Garfield WTP in October 1986.

		BOD (mg/L)		TSS (mg/L)	
		Ecology Laboratory	Colfax Laboratory	Ecology Laboratory	Colfax Laboratory
Influent	Ecology	110	114	110	84
	Garfield	96	159	210	134
Effluent	Ecology	48	33	24	22
	Garfield	42	37	19	30

BOD effluent results from the Colfax lab were slightly lower than those from Manchester (48 vs. 33 mg/L or 32 percent lower; 42 vs. 37 mg/L or 12 percent lower). TSS results for the Ecology composite sample were nearly equal. But the Colfax result from the Garfield composite was 160 percent higher (19 vs. 30 mg/L) than Manchester's result.

There does not appear to be satisfactory correspondence between the two labs. The results from the Colfax lab are not consistent enough for NPDES permit verification. The Colfax lab should be given a specifically designed quality assurance evaluation which should include replicated sampling.

Samples of anaerobically digested and dried sludge were taken for metals analysis as part of the survey. The results are summarized in Table 4. The results indicate that Garfield WTP sludge has very low metals concentrations.

Table 4. Metals concentrations in dried sludge from Garfield WTP in October 1986. Results are compared to data collected during previous Class II inspections at other wastewater treatment (trickling filter) plants in this state (Heffner, 1986).

	Garfield	Previous Surveys		
Metal	Concentration (ug/g dry wt.)	Geometric Mean (ug/g dry wt.)	Range (ug/g dry wt.)	Number of Samples
Cadmium	0.15	5.6	1.0 - 31.3	16
Chromium	1.1	40	8.9 - 180	16
Copper	45.5	500	190 - 1320	16
Lead	3.5	297	156 - 566	16
Nickel	0.84	28.5	19.7 - 41.1	14
Zinc	40	1600	1110 - 2310	16

Silver Creek Receiving Water Survey

The major source of flow in the upper end of Silver Creek at the time of the survey was the WTP. Stream flow was visually estimated to be 1 to 3 gallons per minute (0.007 cfs) at river mile (r.m.) 5.4. The flow at r.m. 4.6 was estimated to be the difference between the flow at r.m. 3.9 cfs and that of the WTP (0.05 cfs, Table 5). WTP flow accounted for nearly 70 percent of the flow at r.m. 3.9, about a half-mile downstream. Stream flow increased 2.5 times at r.m. 2.2 likely due to input from Silver Springs above the sampling point (Figure 1). At this point the percentage of effluent accounted for 28 percent of the flow. An additional 0.2 cfs was added between r.m. 2.2 and the stream mouth. The estimated percentage of WTP effluent at the river mouth was 20 percent.

According to Velz (1970), travel time through a stretch of stream can be estimated by dividing the channel volume by the stream flow. The channel volume can be calculated by multiplying the average cross-sectional area of the channel by the length of the stretch. Travel times in the uppermost three stretches were estimated using the cross-sectional area at r.m. 3.9 (0.5 square foot). This value was assumed to be typical throughout the three stretches. The travel time through the uppermost stretch (r.m. 5.4 to r.m. 4.6) was about 12 hours (assuming a flow of 0.05 MGD at r.m. 4.6).

Travel times for the next two stretches (r.m. 4.5 to 3.9 and r.m. 3.9 to 2.2) were 3 and 11 hours, respectively. (The stream flow was assumed to be 0.16 cfs in these two stretches.) In the lowest segment (r.m. 2.2 to 0.0), travel time was 10 hours. In this case, the cross-sectional area at r.m. 0.0 (2.3 square feet) was assumed to be typical of the stretch and the flow at this point was used in the calculation. The travel time for the entire stream was estimated to be 36 hours; 24 hours from the WTP discharge to the creek mouth.

The section of creek in the vicinity of the agricultural-chemical firms was channelized and bare of vegetation. Above and below this section, the creek channel supported abundant plant growth. Conductivity, chlorides, and all forms of nutrients increased sharply (Table 5) downstream of McGregor Co. (r.m. 5.05). Un-ionized ammonia levels remained far below toxic limits, however. These changes were probably due to several seeps located below an unlined aeration pond operated by the McGregor Co. The pond has since been replaced by a lined pond (C. Nuechterlein, 1987, personal communication). Oxygen was much higher than the substandard levels above the town (r.m. 5.4). Both oxygen and temperature fluctuated widely at r.m. 5.05, probably due to daily warming by the sun of the unshaded sides and bottom of the stream channel.

There is an unexplained source between r.m. 5.05 and r.m. 4.6. Conductivity, chlorides, COD, fecal coliforms, nitrogenous nutrients and phosphorus increased sharply in this stretch. The resulting un-ionized ammonia substantially exceeded the 1-hour toxic criterion

Table 5. Water quality data from Silver Creek during a receiving water study in 1986. Data from Garfield WTP are included. Results also include appropriate water quality standards.

Station	Date	Time	Station Description	Flow (cfs)	Temp. (^oC)	D.O. (mg/L)	D.O. (% sat.)	pH (S.U.)	Sp. Cond. (umohs/cm)	Cl. (mg/L)	COD (mg/L)	Fecal Coliform (#/100 mL)	$NO_3 + NO_2$ (mg/L)	Ammonia (mg/L)			T. Phos. (mg/L)	TSS (mg/L)	Turbidity (NTU)	Chlorine Residual (mg/L)	
														Total	Un-ionized	Criteria[A]				Total	Free
r.m.	10/7	1435	Abv town of Garfield	0.007	10.1	4.2	41	6.9	275	3.6	*	18	0.02	0.01	0.00	0.03	0.28	13	4.0	*	*
5.4	10/8	1200		0.007	10.4	4.2	41	7.3	275	3.8	9	7	0.01	0.02	0.00	0.06	0.22	5	2.0	*	*
r.m.	10/7	1405	Above agri. chemical	*	9.9	11.3	109	7.8	300	6.6	*	1	0.08	0.02	0.00	0.12	0.17	6	1.0	*	*
5.25	10/8	1152	supply firms	*	7.7	10.9	100	7.7	300	6.5	22	1	0.07	0.01	0.00	0.09	0.15	5	2.0	*	*
r.m.	10/7	1400	Below agri. chemical	*	11.1	10.2	101	7.4	455	11	*	1	5.4	0.35	0.00	0.09	0.35	1	2.0	*	*
5.05	10/8	1142	supply firms	*	8.5	8.2	77	7.5	445	11	13	2	4.7	0.44	0.00	0.08	0.41	2	2.0	*	*
r.m.	10/7	1200	Above Garfield WTP	*	10.4	4.9	48	7.5	590	14	*	41	14	31	0.19	0.09	5.2	4	3.0	*	*
4.6	10/8	1030	discharge point	*	9.0	4.9	46	7.4	610	13	39	44	12	24	0.10	0.08	4.0	4	3.0	*	*
Garfield WTP at start of outfall line				0.11	16.0B	6.4B	71B	7.5B	471B	40B	140B	39B	1.1C	11C	0.10C	0.14	6.6C	24C	13B	2.5B	0.2B
r.m.	10/7	1523	Short ditch carrying	*	15.0	5.9	64	7.5	470	38	*	500	2.0	9.4	0.08	0.13	6.5	16	1.4	1.5	0.5
4.5	10/8	1055	WTP eff to Silver Cr.	*	14.9	6.2	67	7.6	570	32	130	54	1.6	12	0.13	0.13	6.5	31	15.0	2.5	0.0
r.m.	10/7	1150	100 meters blw dis-	*	15.1	2.2	24	7.6	520	43	*	16,000	1.0	14	0.15	0.13	5.9	12	1.0	*	NT
4.4	10/8	1040	charge point	*	14.1	2.2	23	7.5	485	30	99	900	0.87	13	0.10	0.12	5.9	10	7.0	*	0.0
r.m.	10/7	1405	Silver Cr. 0.7 mile	0.16	13.5	3.5	37	7.6	480	33	*	6,100	0.10	14	0.14	0.13	6.6	6	3.0	0.0	0.0
3.9	10/8	1040	below WTP discharge	*	10.8	3.8	37	7.5	548	38	60	210	0.14	14	0.09	0.10	6.4	6	4.0	*	*
r.m.	10/7	1447	Silver Creek below	0.42	9.6	8.3	79	7.2	240	7.1	*	52	0.61	0.03	0.00	0.06	0.59	7	2.0	*	*
2.2	10/8	0915	Silver Springs	0.61	8.3	6.6	61	7.3	285	6.3	22	47	0.52	0.03	0.00	0.06	0.51	7	2.0	*	*
r.m.	10/7	0805	Confluence w/Palouse	0.73	7.3	10.1	91	7.7	268	6.3	*	2	0.29	0.01	0.00	0.08	0.30	4	2.0	*	*
0.0	10/8	0830	River at Elberton	*	6.8	10.6	95	7.8	237	6.3	9	7	0.24	0.01	0.00	0.08	0.29	3	2.0	*	*
Water Quality Standard (Class II freshwaters)				*	20	8.0	8	6.5-8.5	*	*	*	100; <10% not to exceed	*	*	*	*	*	*	>5 abv. back-ground	*	*

A = One-hour criterion for un-ionized ammonia (EPA, 1986).
B = Results from average of three grab samples.
C = Results from 24-hour composite sample.
* = Not applicable or no data.
NT = Not taken.

(EPA, 1986). Oxygen decreased significantly. There appears to be a small drainage entering the creek from the north and one agricultural chemical facility (the former Palouse Producers, Inc.) located downstream of r.m. 5.05. Either could be the source. It appears to be very concentrated. A number of cattle graze near the stream in this stretch. But fecal coliform levels at r.m. 4.6 were within the water quality standard and clearly too low for animal waste to be the source.

Fecal coliforms violated water quality standards below the plant discharge (r.m. 4.4). Grazing animals were a source. There was abundant waste on the stream banks, and a major animal crossing at r.m. 4.4, downstream of the discharge. On the other hand, FC levels in the short ditch (connecting the discharge line to the stream) were quite high (500 col./100 mL on October 7, 1987; Table 5). The short discharge ditch also contained abundant growth of Sphaerotilus, an iron-fixing filamentous bacteria that thrives in organic-rich environments (APHA, 1985), possibly due to the presence of WTP effluent. It is possible that FC from the WTP may occasionally reach higher levels than indicated in this study (Tables 1 and 5) due to uneven chlorination caused by intermittent plant flow.

It appears that effluent diluted the nitrate+nitrite and ammonia in the receiving water. On the other hand, the WTP increased chloride, COD, turbidity, and TSS substantially. Total phosphorus and oxygen remained relatively unchanged and un-ionized ammonia was at or slightly above the 1-hour toxic criterion set by EPA (1986). Temperature and pH remained within the state water quality standard. Oxygen levels were substandard, but it would be difficult to separate the role of the upstream source from the plant discharge. Total residual chlorine at r.m. 4.4 was over 100 times higher than the 1-hour criterion (0.019 mg/L) set by EPA (1986). The chlorine in the creek was clear evidence of the presence of effluent. It is possible that the excessive levels of chlorine in the stream may have reduced FCs to some extent.

At r.m. 3.9, FC remained high. Horses pastured nearby had direct access to the stream near the sampling site. Thus FC levels in the stream was likely a mixture of near and distant sources. Ammonia and total phosphorus remained high, although nitrate+nitrite was substantially reduced. Un-ionized ammonia remained near toxic levels. Oxygen was low, although higher than at r.m. 4.4., immediately downstream from the WTP discharge. Total residual chlorine was absent.

The diluting effect of Silver Springs was obvious at r.m. 2.2. Conductivity, chloride, COD, and temperature were substantially reduced. Low ammonia and high nitrate+nitrite suggest the occurrence of nitrification (the bacteria-mediated conversion of ammonia to nitrate) in this stretch of stream. Un-ionized ammonia was absent. Total phosphorus and COD were sharply reduced. A change in the character of the stream channel (from grass-choked ditch to a rock-lined stream with turbulence in sections) probably increased aeration rates. Oxygen conditions were improved although still marginal. FC levels were within the limits of the water quality standards.

Water quality at the mouth of Silver Creek (r.m. 0.0) met the standards for all parameters which suggested nearly complete recovery. Nitrate+nitrite was reduced compared to r.m. 2.2, due possibly to primary productivity. However there was little evidence of excessive eutrophication in the stream bed.

Table 6 summarizes an analysis of loads for Garfield WTP and several points in Silver Creek. The chloride load in Silver Creek is derived primarily from the WTP (which makes up 90 percent of the load at r.m. 3.9). Since chloride is a conservative, non-reactive substance, the load downstream should remain constant (or increase if additional sources exist). However, a "loss" of 40 percent occurred at r.m. 2.2, and the load at r.m. 0.0 appears to be low. This may be due to error in the flow measurement, particularly at r.m. 2.2 which had an irregular cross-sectional area. On the other hand, the problem may rest with the chloride analyses.

In order to evaluate this issue, a "conductivity load index" was calculated. Since conductivity should vary directly with chloride, the index should decrease at r.m. 2.2 as did the chloride load. The "conductivity load index" was calculated by multiplying the flow in the stream by the conductivity. Since conductivity is a physical characteristic rather than a concentration, the use of the term "load" is inappropriate. Table 6 shows that the index increases continuously throughout the stream and did not drop at r.m. 2.2 as did the chloride load. Thus the chloride results may be suspect. In any case, care must be taken in drawing inferences from the analysis, particularly downstream.

The loads above the discharge ditch (r.m. 4.6) were added to those of the WTP to compare with r.m. 3.9, the next site downstream. High nitrate+nitrite and ammonia from upstream of r.m. 4.6 produced significant nitrogen loads despite low flow. Loads of these materials were higher than those from the WTP. These were likely due to the unidentified upstream source(s) discussed earlier.

There appeared to be highly significant unidentified sanitary sources below the WTP discharge point. Only a small fraction of the FC load at r.m. 3.9 could be explained by upstream sources. The very high FC load suggests that grazing animals and/or variable chlorination contributed substantially to downstream FC loads. An unknown fraction of the load may also be due to regrowth of FC in stream bed sediments and subsequent release during disturbance.

Total inorganic nitrogen (TIN) at r.m. 3.9 was about 40 percent lower than the sum of the upstream loads. Ammonia was only slightly reduced, but nitrate+nitrite was reduced substantially. The reduction of nitrate suggests a high rate of primary productivity. But total phosphorus (which should decrease proportionally) did not change. It is possible that an additional phosphorus source exists between r.m. 4.4 and r.m. 3.9, but there is no evidence for this at present.

Table 6 shows that ammonia decreased 11.9 lbs/day between r.m. 3.9 and r.m. 2.2. The reduction was likely due to nitrification. But the

Table 6. Loads calculated for several points in Silver Creek from data collected during a study in October 1986.

Station	Flow (cfs)	Chloride (lbs/day)	Spec.[1] Cond. Load Index	Chemical Oxygen Demand (lbs/day)	Fecal Coli. No./day (E+07)	Nitrate + Nitrite (lbs/day)	Ammonia (lbs/day)	Total Inorg. Nitrogen (lbs/day)	Total Phosphorus (lbs/day)	Total Suspended Solids (lbs/day)
r.m. 4.6	0.05	3.8	30	10.7	5	3.5	7.5	11.0	1.3	1
Garfield WTP	0.11	24.0	52	67.0	10	1.1	6.7	7.8	3.8	13
WTP + r.m. 4.6	0.16	27.8	82	77.7	16	4.6	14.2	18.8	5.1	14
r.m. 3.9	0.16	30.9	77	51.5	430	0.1	12.0	12.1	5.6	5
r.m. 2.2	0.52[2]	18.8	131	61.7	64	1.6	0.1	1.7	1.5	20
r.m. 0.0	0.73	24.6	196	35.2	7	1.02	0.04	1.0	1.2	16

[1] Spec. Cond. Load Index = Flow x specific conductivity (considered to be unitless).

[2] Average of two flows; October 7 and 9.

nitrate+nitrite load increased by only 1.5 lbs/day in the same stretch and part of this load was probably input from Silver Springs. The "lost" nitrate was probably incorporated into plant tissue through primary production. The oxygen required for nitrification was supplied by aeration and primary production, but the supply exceeded the demand only slightly. Relatively low oxygen levels prevailed at r.m. 2.2 (Table 5).

Although there was little evidence of eutrophication in swift-moving channels, there was abundant growth of aquatic plants in slow-moving stretches. It appears that Silver Creek may be nitrogen-limited due to the abundance of phosphorus. The ratio of nitrogen masses to phosphorus required to produce a mass-equivalent of plant material is about 7:1 (Welch, 1980). The ratio of nitrogen (inorganic) to phosphorus (total) at the mouth of Silver Creek (r.m. 0.0) was about 1:1 (Tables 5 and 6). The low ratio suggests that Silver Creek may have been nitrogen-limited at the time of the survey.

CONCLUSIONS

1. The Garfield WTP exceeded the monthly average limit for BOD and percent BOD removal failed to achieve the required BOD removal. TSS seemed to comply with the monthly average criterion, but the plant exceeded the required TSS removal. Loading of BOD and TSS were within permit requirements. The plant conformed to the NPDES limit for pH and fecal coliform bacteria.

2. The WTP needs to add a separate secondary clarifier. The Parshall flume was inaccurately constructed. The present operation of the trickling filter arm is intermittent rather than continuous. Both need repair. Intermittent discharge may result in inefficient chlorination of the effluent.

3. Garfield WTP's contract laboratory at Colfax lacks comparability with the Manchester Environmental Laboratory.

4. The WTP contributes to violations of the state water quality standard for dissolved oxygen and toxic levels of ammonia in the upper end of Silver Creek. The WTP may partially contribute to FC violations also.

5. There are one or more important sources located between the WTP discharge and the McGregor Co. agricultural chemical facility. These (as yet) undiscovered sources contribute significantly to pollutant loads into Silver Creek.

6. The treatment plant discharges highly toxic chlorine residuals into the creek. Grazing animals appear to be the main source of FC violations in the stream. But the WTP may partially contribute due to inefficient chlorination related to intermittent plant flow. FC levels in the stream may be increased by bacterial regrowth in the stream.

7. Garfield WTP contributes about 70 percent of the flow in the upper end of Silver Creek, ranging to 20 percent at its confluence with the north fork of the Palouse. High levels of nutrients may increase the potential for eutrophication in Silver Creek. Silver Creek may be nitrogen-limited because of high levels of phosphorus from the WTP.

RECOMMENDATIONS

1. The WTP should be upgraded to achieve a higher level of treatment. A separate clarifier should be added. The Parshall flume should be rebuilt, the trickling filter should be changed to permit continuous operation, the ladder on the biofilter should be replaced, and chlorination practices reviewed.

2. A special quality assurance study should be conducted on the Colfax laboratory using replicate and spiked samples.

3. Upgrade of the WTP should include removal of direct discharge to prevent ammonia and chlorine toxicity in Silver Creek. In the event that land disposal is impractical, chlorine levels should be limited to meet the water quality criterion. This would likely require dechlorination of the effluent prior to discharge.

4. A concurrent program should be undertaken to locate and eliminate unknown sources and to fence animals away from the stream.

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